Vol. V. *November, 1903.* *No. 6*

BIOLOGICAL BULLETIN.

ABSORPTION OF THE HYDRANTH IN HYDROID POLYPS.

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In 1900 there appeared a paper[1] by Professor Loeb on the "Transformation and Regeneration of Organs," the first part of which contained a discussion of the process of absorption in campanularia hydroids. His results were obtained from a study of the effects produced on the polyps by placing them in shallow dishes of sea water, so that they were in contact with the glass; under these conditions he found that they were gradually transformed and at length absorbed completely into the stem. To summarize briefly Loeb's account of this process, he states that there is noticeable first a contraction of the animal into the cup, followed by the fusion of the tentacles and later by the withdrawal of the whole polyp — now a shapeless mass of protoplasm — into the stem. This complete transformation he ascribes to contact, since it "is certain that contact with sea-water favors the formation of polyps with their more solid elements, while the contact with solid bodies favors the formation of the more fluid material of the stem or stolon." It seemed probable that a histological examination of these changes, in which the hydroid is represented as transforming and *creeping back into the stem*, might prove of interest, since they involved a complete transformation of well-differentiated structures. Therefore, at Professor Morgan's suggestion, I worked on this subject at Woods Holl during the summer of 1902. I was able to obtain a table first through the kindness of the director, and later was appointed to the Bryn Mawr table.

On examining the literature it will be found that there are frequent references to the absorption or disappearance of polyps. Loeb finds for *Margelis* and *Antennularia* that the polyps

[1] *The American Journal of Physiology*, IV., 1900.

"disappear" when their condition of growth is disturbed — *i. e.*, the former being brought into contact with a solid, the latter being suspended horizontally so that its relation to gravity is changed. *Eudendrium*, according to some workers, sheds its hydranths when brought into the laboratory, but I have also often found absorption occurring under the same conditions, and *Eudendrium tenue*, a smaller and more delicate form than *Eudendrium racemosum*, responds in this way even more constantly. *Pennaria*[1] has recently been examined by Cerfontaine who finds that the day after the hydroids have been collected "ca matérialse trourait dans un mauvais état, les polypes qui persistaient étaient morts, les parties mollas s'étaient retireés dans la perisarque et les extremitées du cœnosarque réduit s'étaient cicatricées. Si l'ou conserve les branches, en maintenant une circulation d'eau de mer, ou les voit souvent reprendre de la vigueur. . . . Ou peut de cette façon déterminer expérimentalement une repetition de la regeneration spontanée. A la suite des troubles brusques produits dans les conditions d'être de ces organismes, par la récolte, le transport, le changement d'eau, le changement de température, de lumière, etc., ou determine rapidement la destruction des polypes ; mais bientôt, il semple se produire une acclimation rapide, et aussitôt une nouvelle régénération commence." *Tubularia* never absorbs its polyps but sheds them soon after being collected, and after a day or so if undisturbed, new polyps grow out from the old stalk, a new growth of stalk also taking place behind the head.

It seemed possible that the absorption of the heads of *Campanularia* might be analogous to that in these other forms, in which case it should occur even when not in contact with solids. To test this, I left the hydroids still growing on bits of wood, and placed them in the dishes, so that they were completely surrounded by water. Nevertheless the polyps began to absorb and by the end of twelve hours had almost entirely disappeared, while a few new ones were beginning to form from the old stalks. I also noticed on examining dishes of unused hydroids that had been standing over night, a large percentage of absorbing polyps.

[1] "Recherches expérimentale sur la Régénération et l'Hétéromorphose chez astroides calycularis et Pennaria Carolinii," *Archives de Biologie*, XIX., 1902.

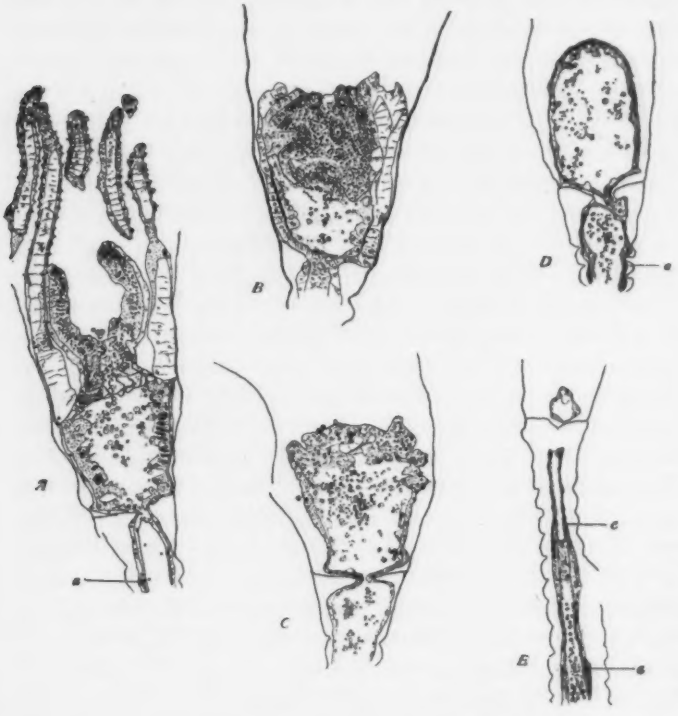
These results show that contact cannot in any case be considered the only factor to which the absorption of campanularian polyps is due, and that the process closely resembles that in other polyps in which under similar conditions we find either absorption or direct shedding of the hydranths with subsequent regeneration.

The material for study was obtained fresh each day, so that the animals should be in thoroughly good condition. Pieces of *Campanularia* were then cut and laid in watch crystals in contact with the glass in the way described by Loeb. The stages in the absorption of *Eudendrium* and *Pennaria*, which I used for comparison, being more difficult to obtain, were taken whether in contact or not, according to where they presented themselves. All the material was killed in cold corrosive acetic, and stained with Delafield's hæmatoxylin and congo red.

Within a few minutes after the removal of a piece or stalk, the cut end closes over, and the digestive current begins to flow slowly from one end of the hydroid to the other. It passes forward, and then is driven backward mainly by the contraction of the circular muscles of the polyps in the region just below the tentacles, but not involving a contraction of the whole animal; a slight pause occurs between each change in direction. The irregularity in the contraction of the polyps sometimes complicates the course of the current. At first the polyps remain expanded, and the only change noticeable is in the digestive fluid which becomes more and more laden with spherical granules of all sizes. The current is sometimes driven with such force that the contents break their way through a newly formed stolon or through the mouth of the polyp. The animal has up to this time been fully expanded except for the rhythmic contractions which decrease only the diameter of the body, but now it gradually contracts into its cup, and the body becomes shorter and broader, the latter change being largely due to the thickening of the ectoderm as can be seen even in the living animals. The tentacles undergo excessive contraction, becoming a crown of mere stubs, and then disappear altogether; their cells passing into the cavity of the polyp. At the same time, the hypostome absorbs.

These changes take some time and normally occupy at least

two thirds of the time required for the complete disappearance of the polyp; sometimes the digestive current may, at this stage, distend the degenerating polyps and delay absorption for several hours. The usual time required is from six to twelve hours, but under the same conditions it may last from one to two days. The size of the structure left in the cup becomes slowly less and



less, and at last the tiny ball of matter is drawn into the stem. I examined the living material carefully for signs of the breaking of the protoplasmic threads that stretch from the cœnosarc to the perisarc just below the cup, but I was unable in most cases to find any trace of it, until the last stage. At that time the strands break and the cœnosarc is drawn out in a fine thread. The protoplasm has been under a strain for the greater part of

the time, due to the growth of the stolon, but the protoplasm of the polyp cannot apparently be *drawn* through into the stem until it has reached a certain stage in its absorption.

The finer structure of normal *Campanularia* is as follows: The ectoderm cells which are flat on the body become cubical on the hypostome; there are no nettle cells except an occasional wandering one, until we come to the upper half of the tentacles. Below the cup lie masses of nettle-forming cells, somewhat irregular in their position, but never found in an quantity anterior to the first annulation. The endoderm is well differentiated on the hypostome into deeply-staining goblet cells and long spindle-shaped cells; in the walls of the body cavity there are large, clear endoderm cells and smaller granular gland cells. The tentacles contain a single row of endoderm cells. These are separated from those of the body cavity by a lamella at the base of the tentacle. Signs of change first arise in the endoderm of the body and the digestive current becomes filled with degenerating endoderm and gland cells, pinched-off portions of cytoplasm and loose nuclei. This process continues for some time without the appearance of any other change, except that as the endoderm becomes less, the lamella slowly contracts, becoming correspondingly thicker, and the ectoderm, having less surface to cover, changes from a thin layer to a much thicker one. The tentacles have also contracted to an abnormal extent, and at last by the breaking of the lamella across their base the endoderm cells round up and pass out into the body cavity. At this stage the tentacles are crowded together, and, the ectoderm being thrown into folds by the excessive contraction, frequently give, in surface view, the effect of being fused, as stated by Loeb. But by careful study the independence of the tentacles can be traced in spite of the closeness with which they are pressed together.

Soon after the endoderm has begun to pass out from the tentacles the lamella breaks near the tip and masses of nettle and ectoderm cells are poured into the cavity. The hypostome also degenerates, the ectoderm cells passing out rapidly into the digestive current and the lamella contracting after them. Soon the lamella of the hypostome breaks and disappears and the mass of ectoderm is also turned in. The polyp is now simply a shell of

ectoderm and endoderm which are separated by the elastic lamella, which usually meets more or less completely at the oral end after the material of the tentacles and hypostome has been absorbed. At this time the lamella breaks in places and more cells from the ectoderm pass through. There is also a small amount of degeneration on the outside, and by these means the amount of ectoderm rapidly diminishes. Gradually the structure becomes smaller and smaller and finally the last fragment is drawn out of the cup. If there are many cells loose in the body cavity of the polyp at this time, they frequently break through the thin wall and pass out into the water.

The best guide by which to determine the amount of protoplasm drawn into the stem, was found to be the masses of nettle-forming cells before alluded to. The cells really drawn represent a very small fraction of the original number. The greater majority have been thrown into the digestive current, from which many are absorbed by the endoderm cells throughout the entire colony.

To compare the process in *Campanularia* with that in other hydroids, I examined both *Eudendrium* and *Pennaria* in which "absorption" also occurs and found the process again one of degeneration. From the time when the first degenerating masses are seen in the digestive current to the final drawing through of the small degenerated mass, the method is almost identical with that in *Campanularia*.

Recently there has appeared a paper by Gast and Godlewski, Jr., on the degeneration of the polyps of *Pennaria*[1] who have obtained results similar to my own.[2] It is interesting to note that their material was taken from polyps which had regenerated their heads in the laboratory, and then after two or three days had begun to absorb again — a different condition from that under which mine were obtained, yet the process is the same. Since these investigators have fully covered the ground for *Pennaria*[3] I shall not describe the changes in that form and indeed merely speak of two or three points in the degeneration of *Eudendrium*

[1] "Ueber den Regulationsersheinungen bei Pennaria carolinii," *Archiv für Entwickelungsmechanick der Organismus*, XVI., 1903.

[2] See preliminary note, BIOL. BULL., IV., 2, 1903.

[3] Probably another species.

that differ from that in *Campanularia*. The degeneration of the endoderm is much more rapid, the cells breaking down more completely and filling the digestive cavity with fine protoplasmic granules. Since there is no lamella across the bases of the tentacles, the endoderm can also pass out from them more readily. The loss of ectoderm is here also accomplished by the passing in of cells through breaks in the lamella, the edges of which are apt to draw together again. The complete disappearance of the lamella does not occur until a very late stage. At the end the whole of the remaining structure is not always drawn through into the stalk, but an ill-defined mass of protoplasm is often left at the end.

The constant position of the ectodermal gland cells near the beginning of the stalk throughout the degenerative changes show that there is no drawing of cells into the stem until the final stages.

The histological evidence thus supports my observations on the living animals, that in *Campanularia* we have to do with no transformation of the protoplasm due to contact, but with a degeneration of the polyp. Similar changes take place in other hydroids, and occur apparently when they are subjected to abnormal or harmful conditions.

I wish to express my thanks to Professor Morgan for his suggestions and kind supervision of my work.

FORM REGULATION IN CERIANTHUS.

II. The Effect of Position, Size and Other Factors upon Regeneration.

C. M. CHILD.

In the preceding paper (Biol. Bull., Vol. V., No. 5, 1903), the course of regeneration in cylindrical pieces from the middle region of the body was described, since such pieces afford a typical result and serve as a basis for comparative study. It is desired in the present paper to call attention to certain conditions which influence the result, either as regards time or quantity.

The principal features in the regeneration of *Cerianthus* may be reviewed as follows: the collapse of the piece after section and the infolding of the ends; the closure of the ends by new tissue and the gradual distension of the piece and the increase in the area of the new tissue at the ends in consequence of the accumulation of water in the enteron, probably by diffusion through the body-wall; the reduction and disappearance of the muscular layer and pigment at both ends; the regeneration of mesenteries; the outgrowth from the tentacular ridge of a marginal tentacle over each intermesenterial chamber; the formation of the mouth in the directive radius; the appearance of the labial tentacles in a circle upon the disc; the outgrowth of new tissue at the aboral end of the piece.

Since each of these processes is gradual it is impossible to determine with exactness the time of its beginning; moreover, the various processes overlap and are connected in such a manner that it is difficult to separate distinct stages except arbitrarily. For these reasons the comparison of different pieces with a view to determining the conditions which effect regeneration can best be accomplished by the examination of these pieces at stated times, rather than by noting the time at which a given piece arrives at a particular stage. The former method not only allows direct comparison of the pieces, and thus often renders the detection of slight differences less difficult, but it obviates the necessity for

almost continuous observation and the accompanying manipulation necessary to examination, which is a source of irritation to the regenerating pieces and may often effect the result by causing rupture of new tissue or other injuries.

In general then the method pursued in the experiments was that of examining at intervals pieces to be compared and noting the condition of each. Owing to the number of points to be observed and the necessity for indicating slight differences any arrangement of the results in tables is unsatisfactory: they are given, therefore, in much the same manner as first recorded. The series of experiments described are selected from a large number but the results were remarkably uniform in all cases. In the description of the stages only the most salient features of the regeneration are mentioned in most instances. In all cases, however, unless definite statement is made to the contrary, regeneration proceeded in the typical manner.

I. DESCRIPTION OF EXPERIMENTS.

Series 22.[1]

September 24, 1902. The oral end, including the œsophageal region, was removed from twenty-three large specimens of *C. solitarius* and the remaining portion of the body was divided by a transverse cut as nearly as possible into two equal pieces (Fig. 1), oral halves being designated A, aboral B. All of the pieces A were placed in one aquarium, all of B in another.

September 27: Three days after section:

A. Most of the pieces are still collapsed, but in a few the ends are closed and a slight distension with water is evident.

B. All still collapsed.

September 28: Four days after section:

A. All the pieces are more or less distended with water: three pieces show the tentacular ridge and the first traces of marginal tentacles.

B. Three pieces are closed and somewhat distended, the remainder still collapsed.

September 29: Five days after section:

[1] The series retain the numbers given them in my notes.

A. Distinct marginal tentacles are present on eight pieces; the remainder all distended and with tentacular ridge.

B. All closed and more or less distended; in a few distension is just beginning; none with distinct tentacles.

September 30: Six days after section:

A. All with distinct marginal tentacles from 0.5–1.0 mm. long.

B. The pieces which were the first to close and become distended show traces of marginal tentacle buds; all pieces distended with water.

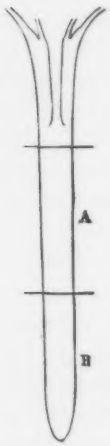


FIG. 1.

October 1: Seven days after section:

A. All with marginal tentacles 1.0–2.0 mm. long.

B. Traces of marginal tentacles on all pieces except those which were the last to close.

This series was not kept under observation for the later stages. As regards the earlier stages, however, it shows clearly that the aboral pieces regenerate somewhat less rapidly than the oral pieces, although the latter are cut at both ends, the former at only one end. The difference between the two sets of pieces is universal, not even the most advanced pieces in the set B showing as rapid regeneration as the least advanced of A. In general the differences between pieces of the same set are slight.

SERIES 45.

November 7, 1902. Tentacles and disc were removed from four specimens and the remaining portion of the body was cut into four pieces, A, B, C, D, as nearly equal as possible (Fig. 2). All of the pieces A were placed in one aquarium, all of B in another, etc. The pieces A contained a part of the œsophagus.

November 9: Two days after section:

A. Ends closed and piece distended; as in other similar cases the cut oral margin of the œsophagus has united with the oral margin of the body-wall so that the pieces possess a well-developed mouth-opening.

B, C, D. All collapsed.

November 10: Three days after section:

A. Marginal tentacular ridge appearing.

B. One piece beginning to fill with water; others collapsed.

C. One piece beginning to fill; others collapsed.

D. All collapsed.

November 12: Five days after section:

A. Marginal tentacular ridge distinct, with fading pigment.

B. All distended; new tissue at ends visible; tentacular ridge forming.

C. One piece distended; new tissue at ends visible; two pieces partly filled but not sufficiently to show the new tissue at the ends; one piece still collapsed.

D. All still collapsed.

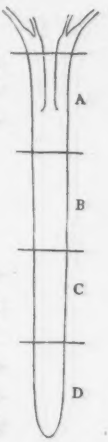


FIG. 2.

November 15: Eight days after section:

A. Marginal tentacles just appearing in all.

B. One piece with marginal tentacles just appearing; three pieces distended; new tissue at ends visible; tentacular ridge distinct, unpigmented.

C. Two pieces distended; new tissue at ends visible; tentacular ridge forming; one piece still collapsed; one piece collapsed and completely enclosed in slime which was removed.[1]

D. All still collapsed.

November 20: Thirteen days after section:

A. Marginal tentacles in all 1 mm. in length.

B. In one piece marginal tentacles 1 mm., in others about 0.5 mm.

C. All distended; tentacular ridge unpigmented, marginal tentacles just appearing.

D. One piece beginning to fill, others collapsed.

November 25: Eighteen days after section:

A. Marginal tentacles 2–2.5 mm. showing faint traces of pigmented bands in two pieces, in other two unpigmented; labial tentacles 0.5 mm. At aboral end new outgrowth 2 mm.

B. Marginal tentacles 1–2 mm., some differences in length appearing in individual pieces, unpigmented; a few labial tentacles

[1] The complete enclosure of pieces in slime, as in a cyst, often occurs when they remain collapsed for more than four or five days. The slime being secreted all over the ectoderm unites at the infolded ends and forms a complete cyst from which the piece is unable to emerge after a few days.

just appearing in each piece. At aboral end new outgrowth about 2 mm.

C. In two pieces marginal tentacles 0.5–1.0 mm., in other two slightly less advanced; in all unpigmented: none with labial tentacles. At aboral end no distinct outgrowth of new tissue.

D. One piece partly filled, others collapsed.

December 2: Twenty-five days after section:

A. Marginal tentacles about 5 mm., with distinct transverse pigment bands; labial tentacles 1–1.5 mm. Aboral end as before.

B. Marginal tentacles 3.5–4 mm., pigment bands visible but lighter than in A; labial tentacles 0.5–1 mm. Aboral end as before.

C. Marginal tentacles mostly 3 mm., a few in two pieces 4 mm., all unpigmented; labial tentacles just appearing. At aboral end no distinct outgrowth of new tissue.

D. One piece partly filled, but enclosed in slime which was removed; others still collapsed.

December 12: Thirty-five days after section:

A. Marginal tentacles 6–7 mm., pigment bands dark: labial tentacles about 2 mm. At aboral end outgrowth of new tissue 2–3 mm.

B. Marginal tentacles 5–6 mm.; pigment bands lighter than in A; labial tentacles 1–1.5 mm. At aboral end outgrowth of new tissue 2–3 mm.

C. Marginal tentacles 4–5 mm.; pigment bands visible, but slightly lighter than in B; labial tentacles about 1 mm. At aboral end outgrowth of new tissue 1 mm.

D. One piece closed and partly filled as before, but no traces of tentacular ridge. Three pieces still collapsed and enclosed in slime which was removed.

The series as a whole was concluded at this time, since the only further changes in A, B and C consist of a slight increase in length of the tentacles and the pigmentation. The pieces D, however, which had not as yet shown any traces of regenerating tentacles were kept under observation until January 21, 1903. Up to this time only the one piece which had become partly filled showed any signs of regeneration, the others remaining completely collapsed and surrounded by slime, which was removed

from time to time in order to permit distension to occur if there were any tendency. The changes during this time in the one piece which was closed and partly filled are of considerable interest. At one side of the closed oral end of the piece a few minute outgrowths 0.2–0.5 mm. in length made their appearance. They resembled marginal tentacles and were situated where these organs should appear, but there were only a few of them close together on one side and no others appeared. Fig. 3 shows the piece as it appeared January 21. The new tissue closing the end is indicated by the stippling. At one side are six small outgrowths resembling tentacles, but no traces of any others can be found at any point of the circumference. At the conclusion of the experiment the piece was opened and it was found that a few of the longest mesenteries extended into the piece in the radius in which the outgrowths appeared. This region is then without doubt the region of the directive mesenteries, and the mesenteries present are simply the longest mesenteries of the body which lie to the right and left of the short directives and extend nearly to the aboral end. The small outgrowths correspond in position with the spaces between these mesenteries and there can be little doubt that they represent marginal tentacles. No other mesenteries are present in the piece, none having regenerated. It becomes evident from the history of this piece that the presence of mesenteries is necessary for the regeneration of marginal tentacles. In pieces from regions nearer the oral end mesenteries are regenerated, but in this piece no trace of regenerated mesenteries could be found, and tentacles have begun to regenerate only in the spaces between such of the old mesenteries as extended into the piece.

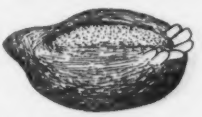


FIG. 3.

The series as a whole affords several results of importance. As in the preceding series, the decreasing rapidity of regeneration with increasing distance from the oral end of the body is clearly shown. The pieces A regenerate more rapidly than B, B more rapidly than C, and finally D, the aboral pieces, are capable of only a slight degree of regeneration or of none at all, the difference between the one piece which regenerated a few tentacles and

the others probably being due to the fact that the cut separating C from D in the one case was slightly more oral than in the other three.

The differences in the rapidity and the amount of regeneration are best shown at the oral ends of regenerating pieces, for it is difficult to determine with exactness the amount of actual new tissue at the aboral ends of the pieces, since the line of demarcation between the unpigmented tip and the normally pigmented regions oral to it is not at all sharp, extending in many cases over two to three millimeters. As regards the aboral ends the pieces A and B showed little difference, but regeneration at the aboral end of C was in all cases distinctly less than in A and B.

In general the series seems to indicate that not only is regeneration less rapid with increasing distance from the oral end, but that there is a corresponding difference in the amount of regeneration. In the pieces A, B and C the differences are comparatively slight, though without doubt present as can be seen by comparing the data for these pieces thirty-five days after section. When the pieces D are taken into consideration, however, the difference between these and all other pieces is marked, for in no case did these aboral ends show anything approaching complete regeneration. There is then, according to these results, a rapid decrease in regenerative power near the aboral end of the body, and apparently complete absence of this power in an aboral region representing approximately one fifth of the body-length. As will be shown below, much smaller pieces than this from other regions of the body are capable of complete regeneration; moreover, the size of the area within which regeneration does not occur differs according to conditions.

Series 54 and 55.

December 15, 1902. The tentacles, disc and œsophageal region were removed from twenty large specimens; ten of the remaining pieces were then divided by a transverse cut into two pieces, A and B (Fig. 4), the cut being made near the aboral end so that the pieces A comprised the greater part of the body aboral to the œsophagus, while the pieces B represented the extreme aboral end, about one sixth of the body-length. These two sets of pieces constituted Series 54.

Each of the remaining ten pieces was also divided by a transverse cut into two pieces A and B, but in this case the cut was made near the oral end of the piece (Fig. 5), so that A repre-

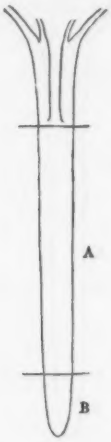


FIG. 4.

FIG. 5.

sents one sixth of the body-length from the region just aboral to the œsophagus, while B is the whole remaining portion of the body. These pieces constitute Series 55.

In this manner four sets of ten pieces each were obtained. The oral ends of pieces 54A and 55A represent approximately the same level in the body of the individuals from which they were taken, while their aboral ends lie at very different levels; moreover, the pieces 54A are about four times as long as 55A. The oral ends of the pieces 54B and 55B are at very different levels, while their aboral ends are the aboral ends of the parent bodies; 55B is about four times as long as 54B.

In 54A and 54B we have pieces differing widely in size and with oral ends at very different levels; the same is true of 55A and 55B, but the relations of size are reversed.

The comparative study of the regeneration of those four sets of pieces should afford data regarding the rapidity and amount of regeneration at different levels of the body and in pieces of different sizes.

December 19: Four days after section:

54A. All with closed ends and filling with water, but ends not yet expanded so as to show new tissue.

54B. All collapsed.

55A. All with closed ends and filling with water, but ends not yet expanded. Condition same as in 54A.

55B. Ends closed, but pieces contain less water than 54A and 55A.

December 22: Seven days after section:

54A. All distended, ends expanding, new tissue visible; tentacular ridge just appearing.

54B. All collapsed.

55A. Similar to 54A.

53B. All filling with water, but none distended sufficiently to expand the ends and show new tissue.

December 24: Nine days after section:

54A. Tentacular ridge distinct, with fading pigment.

54B. All still collapsed.

55A. Similar to 54A.

55B. All distended, ends expanded and tentacular ridge just appearing.

December 26: Eleven days after section:

54A. Marginal tentacles just appearing in some specimens as minute outgrowths from tentacular ridge, which is now unpigmented.

54B. All still collapsed.

55A. Similar to 54A.

55B. Tentacular ridge with fading pigment, but less distinct than in 54A; no marginal tentacles.

December 28: Thirteen days after section:

54A. Marginal tentacles 0.25–0.5 mm.

54B. All still collapsed.

55A. Similar to 54A.

55B. Tentacular ridge distinct, unpigmented in most cases; in a few the earliest traces of marginal tentacles visible.

January 3, 1903: Nineteen days after section:

54A. Marginal tentacles 2–3 mm.

54B. All still collapsed, much contracted, rounded in form.

55A. Similar to 54A.

55B. Marginal tentacles 1–1.5 mm.; in one specimen with rather unequal tentacles a few 3 mm.

January 11 : Twenty-seven days after section :

54A. Marginal tentacles 5–6 mm.; transverse bands of pigment distinct; labial tentacles 1–1.5 mm. At aboral ends no well-marked outgrowth of new tissue; ends slightly lighter in color at region of closure.

54B. All still collapsed, much contracted, rounded in form.

55A. Oral ends similar to 54A. At aboral ends a distinct outgrowth of new tissue 2–3 mm.

55 B. Marginal tentacles 3–5 mm.; pigmentation of tentacles slightly less deep than in 54 A ; labial tentacles just visible — 1 mm.

January 21 : thirty-seven days after section :

54 A. Marginal tentacles 7–8 mm.; labial tentacles 1–1.5 mm. No distinct outgrowth of new tissue at aboral ends.

54 B. Collapsed, rounded and still further reduced in size.

55 A. Marginal tentacles 6–8 mm.; labial tentacles 1–1.5 mm. At aboral ends distinct outgrowth of new tissue 3–5 mm. At this time the average length of the marginal tentacles in these pieces is somewhat less than in 54 A. In the latter cases there are fully as many specimens with tentacles 8 mm. in length as with tentacles 7 mm. In 55 A, however, only a few pieces, and these the largest, possess marginal tentacles 8 mm. in length ; in nearly all the marginal tentacles are 6–7 mm. Moreover, the average length of the labial tentacles in 55 A is slightly less than in 54 A. These pieces are evidently falling behind the longer pieces.

55 B. Marginal tentacles 5–6 mm., somewhat less deeply pigmented than in 54 A ; labial tentacles 1 mm.

At this time the regenerated structures had acquired their maximum size ; afterward reduction in size, which always occurs in the pieces kept without food, began. For present purposes it is not necessary to follow the history of these pieces further.

Comparison of the data afforded brings to light a number of interesting results. Comparing the rapidity of regeneration in the different pieces, it is seen that the oral ends of pieces 54 A and 55 A, which represent approximately corresponding regions of

the parent body, regenerate with equal rapidity except at the end of the experiment, although pieces 54 A are about four times as long as pieces 55 A. The oral ends of pieces 55 B, which represent a region of the parent body further aboral than those of 54 A and 55 A, regenerate less rapidly than these, although the pieces are about equal in size to 54 A and four times as long as 55 A. And finally, the pieces 54 B, whose oral ends represent a region near the aboral end of the parent, do not regenerate at all.

As regards the aboral ends of the pieces only 54A and 55A need be considered, since no regeneration occurs at the aboral end of a piece when this represents the aboral end of the parent-body, as is the case in 54B and 55B. In 54A and 55A the difference in the rapidity and amount of regeneration at the aboral ends is marked; in 55A, where the aboral ends of the pieces represent a region oral to the middle region of the parent-body the aboral regeneration was much greater than in 54A, where the aboral ends represent a region near the aboral end of the parent-body, even though the pieces 54A were four times as long as 55A.

From all of these facts it is evident that the rapidity and amount of regeneration decrease as the cut surface, either oral or aboral, approaches the aboral end of the parent-body, and that the size of the piece has no marked influence, at least within the limits of size of the present experiment. That the size of the piece does, however, affect the final result in some degree is shown by the condition of pieces 54A and 55A at the end of the experiment 37 days after section; while no differences between the two sets were noted earlier it was found at this time that the smaller pieces 55A were falling slightly behind the larger 54A. Here then a slight influence of size is noticeable, though only in the later stages of the experiment. As will be shown later this result is confirmed by other cases. In pieces above a certain minimal size regeneration is not influenced by the size, except in the later stages.

Series 35.

October 20, 1902. In this case after removal of disc and tentacles a single specimen was cut into four pieces, A, B, C, D as shown in Fig. 6. The piece B was much smaller than the

others and masses of the mesenterial filaments protruded from each end, thus delaying the closure and normal regeneration; it is therefore omitted from the present consideration. The pieces A and C are nearly equal in length and are about two thirds the length of D.

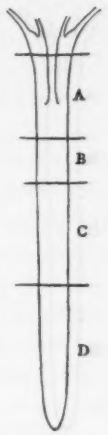


FIG. 6.

October 22: two days after section: All pieces still collapsed.

October 23: three days after section:

A. Margin of œsophagus united with body-wall, aboral end closed and enteron partly filled with water.

C. and D. Both still collapsed.

October 24: Four days after section:

A. Sufficiently distended with water to spread the inrolled margins and allow the œsophagus at the oral end and the new tissue closing the aboral end to become visible.

C. and D. Both still collapsed.

October 25: Five days after section:

A. Distended with water: tentacular ridge visible and pigment disappearing from it.

C. Ends closed by new tissue; distended.

D. Enteron partially filled with water; distension not yet sufficient to separate the infolded oral margins and permit new tissue to become visible.

October 27: Seven days after section:

A. Marginal tentacles just appearing on tentacular ridge.

C. Tentacular ridge distinct; its pigment disappearing.

D. Distended with water; new tissue closing oral end exposed by separation of cut margins in consequence of distension: tentacular ridge visible, with fading pigment.

October 29: Nine days after section:

A. Marginal tentacles 1 mm.

C. Marginal tentacles just appearing on tentacular ridge.

D. Tentacular ridge distinct, without pigment; no tentacles visible.

October 31: Eleven days after section:

A. Marginal tentacles 2 mm. At aboral end new tissue growing out in a small point 1.5 mm.

November 6: Seventeen days after section:

A. Marginal tentacles 5 mm.; labial tentacles 0.5–1 mm. At aboral end outgrowth of new tissue 2 mm.

C. Marginal tentacles 3–4 mm.; labial tentacles 0.5. At aboral end of outgrowth of new tissue 1 mm.

D. Marginal tentacles 1–2 mm.; labial tentacles not yet visible.

November 12: Twenty-three days after section:

A. Marginal tentacles 10 mm.; distinctly marked with the characteristic transverse bands; labial tentacles 2–3 mm. At aboral end margins of old body-wall are becoming involved in the growth and losing pigment; the unpigmented area, including outgrowths, is about 3 mm. in length from aboral end.

C. Marginal tentacles 6–7 mm.; transverse pigment bands visible but not dark as in A; labial tentacles 2 mm. At aboral end new outgrowth 1.5 mm.

D. Marginal tentacles 5–6 mm. still unpigmented; labial tentacles 1 mm.

November 20: Thirty-one days after section:

A. Marginal tentacles 12–13 mm.; pigment bands dark and distinct; labial tentacles about 3 mm. Aboral end as before.

C. Marginal tentacles 8–9 mm.; pigment bands distinct but less dark than in A; labial tentacles 2–2.5 mm. At aboral end unpigmented area 2–3 mm. in length.

D. Marginal tentacles 6–8 mm.; pigment bands visible but less dark than in C; labial tentacles 2 mm.

December 2: Forty-three days after section:

A. Marginal tentacles 12–13 mm.; labial tentacles 3–4 mm. At aboral end the new outgrowth is becoming pigmented.

C. Marginal tentacles 10 mm.; pigmentation of tentacles scarcely distinguishable from that of A; labial tentacles 3 mm. At aboral end the unpigmented area about 3 mm.

D. Marginal tentacles 12–13 mm.; pigmentation slightly less dark than that of A; labial tentacles 3–4 mm.

At this time regeneration is essentially complete in the pieces; no further increase in the length of tentacles, or of the new growth at the aboral end occurs. The marginal tentacles of C and D are still slightly lighter in color than those of A, and the pigment has not yet extended over the aboral outgrowth in C as far as in A, but these slight differences are later eliminated.

Examination of the data shows that at all stages except the final A is more advanced in regeneration than C, and C more advanced than D.

It will be noted also that the regenerated parts of piece A did not increase in size after 31 days, with the exception of the labial tentacles which showed a slight increase between 31 and 43 days. In the piece C a slight increase in the length of all tentacles occurred between 31 and 43 days. In the piece D, however, there was a marked growth during this time. In other words the piece A completed its regeneration first, then the piece C, and last of all the piece D.

Throughout this series then there is a distinct relation between the rapidity of regeneration and the position of the pieces in the parent-body, the rapidity of regeneration decreasing with increasing distance from the oral end.

One other point requires consideration: the regenerated tentacles of the piece D finally attain the same length as those of piece A. This would appear at first glance to contradict the results obtained from other series of experiments where not only the rapidity but the amount of regeneration diminishes toward the aboral end. Comparing A and C, two pieces about equal in size, we find that the amount of oral regeneration in A is greater than in C, as might be expected from comparison with other series, since C represents a region farther from the oral end of the parent-body than A. The piece D, still nearer the aboral end of the parent-body, but much longer than A and C, while regenerating more slowly than either of these finally equals A in the amount of regeneration. Apparently in this case the influence of size has counterbalanced the influence of position. If piece D was of the same size as A and C the amount of oral regeneration would undoubtedly be less than in those pieces, but since it is much larger, *i. e.*, contains much more available material, regeneration continues for a somewhat longer time (note the increase in size of tentacles in D between 31 and 43 days) and the regenerated organs finally, though after a longer time, reach a condition similar to that in A. In this case, as in Series 54 and 55, the influence of size is slight and appears only in the latest stages of regeneration.

SERIES 56.

December 15, 1902. Disc, tentacles and œsophageal region were removed from ten large specimens by a transverse cut aboral to end of œsophagus. The aboral piece was then cut into two pieces, A and B, of equal length (Fig. 7) which were kept for comparison.

FIG. 7.

December 19: four days after section:

A. Nine pieces with ends closed; a few distended, the others partly filled with water; one piece still collapsed.

B. All still collapsed.

December 22; seven days after section:

A. All distended; ends well expanded, showing new tissues in a few pieces the tentacular ridge is just appearing.

B. All still collapsed.

December 26: Eleven days after section:

A. Tentacular ridge distinct, with faded pigment; in a few pieces the first traces of marginal tentacles distinct.

B. Filling with water but not distended; new tissue at oral end not visible.

December 28: Three days after section:

A. Marginal tentacles 0.5 mm.

B. Four pieces fairly well filled with water; tentacular ridge just visible; six pieces collapsed or only partly filled; tentacular ridge not visible.

January 3, 1903: Seventeen days after section:

A. Marginal tentacles 2–3 mm.

B. One piece distended; marginal tentacles 2 mm. Nine pieces partly or completely collapsed; no tentacular ridge or tentacles visible.

Circumstances necessitated the conclusion of the series at this time, so that it was impossible to determine whether the nine pieces of B would ever have regenerated. The series affords, however, some interesting results. As in all other series regeneration is much less rapid in the aboral pieces; in only one case did the aboral pieces regenerate tentacles before the conclusion

of the experiment. Examination of the data shows that the pieces B were all filling with water eleven days after section; that two days later all but four were collapsed, and that, finally, seventeen days after section, only one piece was filled with water. These changes are undoubtedly due to the fact that the growth of new tissue at the ends of these pieces failed to keep pace with the pressure of water in the enteron, and so rupture occurred as soon as the pieces reached a certain point. In only one case did the new tissue remain intact, viz., the case in which tentacles appeared.

As is evident from a comparison with other series, viz., series 22, 35, and 45, regeneration was found to occur in other cases in pieces representing about the aboral third of the body, though pieces representing the aboral fifth (series 45) or less did not regenerate. Why then did regeneration fail to occur in the aboral pieces of the present series? The difference is undoubtedly to be accounted for by the low temperature of the water. This series was begun in December and continued into January. The temperature of the water was very much lower at this time than during the autumn, and several other series begun on the same date showed similar results. In other words, the area at the aboral end which is incapable of regeneration increases as the temperature becomes lower, and in the present series includes more than the aboral third of the body. This point will be discussed in a following section where the influence of temperature is considered.

(*To be Continued.*)

ARTIFICIAL MIXED NESTS OF ANTS.

ADELE M. FIELDE.

Mixed nests of ants are rarely found in nature, and the ants associated in such nests are always of the same subfamily if not of the same genus.[1]

There are two ways of causing ants of different genera, or even of different subfamilies, to live peacefully together. One way is that of destroying the sense of smell in the ants by depriving them of a portion of the antennæ. Forel discovered, in the seventies, that the funicles were the organs of smell. I have had representatives of three subfamilies of ants, all without funicles, living amicably together through several consecutive weeks, although the members of the group varied in size, from the huge *Camponotus pennsylvanicus* to the small *Stenamma fulvum;* in form, from the shark-like *Stigmatomma pallipes* to the chubby *Lasius umbratus;* in color, from the jet-black *Cremastogaster lineolata* to the amber-yellow *Lasius latipes;* and in character, from the truculent *Myrmica rubra* to the patient *Formica subsericea.*

In 1901, using *Stenamma fulvum* for the experiments, I located[2] the appreciation of the nest-aura in the distal segment of the funicle, the eleventh; that of the colony, in the tenth segment; that of the individual track, in the ninth segment; that of the inert young, in the eighth and seventh segments. I have lately located the appreciation of the odor of enemies in the sixth and fifth segments.

I cut off the five distal segments of the antennæ from seven queens[3] of *Stenamma fulvum*, seven queens of *Cremastogaster lineolata*, five queens of *Myrmica rubra*, five queens of *Lasius*

[1] E. Wasmann, "Die zusammengesetzten Nester und gemischten Kolonien der Ameisen," 1891. William Morton Wheeler, "The Compound and Mixed Nests of American Ants," *American Naturalist*, 1901.

[2] A. M. Fielde, "Further Study of an Ant," *Proceedings of the Academy of Natural Sciences of Philadelphia*, November, 1901.

[3] Among the Myrmicine ants, queens only were used for these experiments, because of the abnormal irritability of myrmicine workers lacking parts of the antennæ.

umbratus, seven workers of *Lasius latipes*, five workers of *Camponotus pennsylvanicus*, four workers of *Formica sanguinea*, four workers of *Formica subsericea*, and three workers of *Stigmatomma pallipes*, and when these ants had recovered from shock-effect, with healed wounds, I placed them all in an artificial nest, roomy for their number, having thirty-two square inches of floor-space. Duels were constant, and in two hours there were but twenty-three survivors from the forty-seven ants. Several of the survivors were disabled.

I then formed a new group, with other ants, having the four proximal segments of the funicle intact. This group included representatives of the Camponotines, *Camponotus pennsylvanicus* and *Formica sanguinea;* of the Myrmicines, *Stenamma fulvum* and *Cremastogaster lineolata*, and of the Ponerines, *Stigmatomma pallipes*. These lived peacefully together many days, in one of my small Petri cells, and ants of different subfamilies often huddled together. In this cell I saw a queen of the *Stenammas* lapping regurgitated food from the mouth of a *Camponotus* worker.

In another mixed group, made up of ants retaining from three to six segments of a funicle, I removed and examined every ant that attacked one of another species, and found that all such ants retained more than four segments of the funicle.

We may, then, secure peaceful mixed nests by depriving the inmates of certain segments of the antennæ.

I have lately created many mixed nests by another method, that of educating the ants in ant-odors unlike their own.[1] If one or more individuals, of each species that is to be represented in the future mixed nest, be sequestered within twelve hours after hatching, and each ant so sequestered touch all the others with its antennæ during the three ensuing days, these ants will live amicably together thereafter, although they be of different colonies, varieties, species, genera or subfamilies. For sequestering the ants, I used artificial nests, made in watch-glasses so small that the natural movement of the newly-hatched ants would bring each of them into contact with all the others. In no case did the callows quarrel, and those of most diverse lineage some-

[1] The experiments were made at the Marine Biological Laboratory at Woods Hole, Mass., in July, August and September, 1903.

times snuggled one another. The ant's sense of smell appears to be perfectly acquired, and its standards of correct ant-odor to be established during the first three days after hatching. Any two species or any number of species that I captured for use in these experiments, became accustomed to each other's odor, and therefore friendly, if the early association was close and continuous. This association is more perfect when no inert young distracts the attention of the callows from one another, and when the arrangement of the nest offers no place of seclusion for any of its inmates. Air, humidity and nourishment were provided as in large nests of the Fielde pattern. When the ants had been thus segregated for five days or more, the inmates of several like nests were transferred to a more spacious habitation, and newly hatched ants from the same colonies could be safely added thereafter; but no ant of other lineage nor of greater age was amicably received in any of the mixed nests.

Each of the groups mentioned in the following list existed under my care for a month or more after the cessation of additions of newly hatched ants to their mixed nest.

Myrmicine Ants.

Group 1.—Six queens of *Cremastogaster lineolata* with eighty workers of *Stenamma fulvum.* The workers snuggled the queens as closely as if of the same species as themselves. In each of two watch-glass nests, the sole queen died on the third day after hatching. Newly-hatched queens of the same *Cremastogaster* stock were accepted by the bereaved workers,[1] in the

[1] After these ants in group 1 had been established for two days in a Fielde nest, a raid was made upon them by adult workers, of the queens' stock, that had escaped from the hatchery-nest, and hidden in a crevice in the laboratory. Very early one morning, I discovered that these adult *Cremastogaster* workers had entered the nest in considerable numbers through a rift in the towelling. Some of them were clustering around the young queens, while others were busily employed in dragging the *Stenamma* callows out of the nest. My arrival thwarted an apparent design of the *Cremastogasters* to eject the *Stenammas* and dwell in an unmixed nest with queens of their own.

This first group is noteworthy, because *Stenamma fulvum* and *Cremastogaster lineolata* will each feed their larvæ upon the eggs, larvæ and pupæ of the other. In one of my artificial nests the *Stenammas* lately took care, with their own young, of a great number of *Cremastogaster* larvæ and pupæ, during two months; but every *Cremastogaster* that hatched was instantly killed and cast upon the rubbish-heap.

one case three days, and in the other case five days, after the death of their first queen. I know no adult ants that will accept a queen from another colony of their own species, much less a queen of a genus not their own.

Group 2. — *Myrmica rubra*, *Stenamma fulvum* and *Cremastogaster lineolata*, workers of each species.

One Species of Camponotine Ants with one Species of Myrmicine Ants.

Group 3. — *Lasius latipes* with *Stenamma fulvum*; workers of each species.

Group 4. — *Lasius umbratus* with *Stenamma fulvum*; workers of each species.

Group 5. — *Lasius umbratus* with *Cremastogaster lineolata*; workers of each species.

Group 6. — *Formica sanguinea* with *Cremastogaster lineolata*; workers of each species.

Group 7. — *Formica subsericea* with *Cremastogaster lineolata*; workers of each species.

One Species of Camponotine Ants with two Species of Myrmicine Ants.

Group 8. — *Formica sanguinea* with *Stenamma fulvum* and *Cremastogaster lineolata*; workers of each species.

Two Species of Camponotine Ants with two Species of Myrmicine Ants.

Group 9. — *Lasius latipes* and *Formica lasiodes*[1] with *Stenamma fulvum* and *Cremastogaster lineolata*; workers of each species.

Group 10. — *Camponotus pennsylvanicus* and *Formica sanguinea* with *Stenamma fulvum* and *Cremastogaster lineolata*.

One Species of Camponotine Ants with Three Species of Myrmicine Ants.

Group 11. — *Lasius latipes* with *Stenamma fulvum*, *Myrmica rubra* and *Cremastogaster lineolata*; workers of all four species with one queen of *Cremastogaster lineolata*.

[1] Kindly identified for me by Dr. W. M. Wheeler.

THREE SPECIES OF CAMPONOTINE ANTS WITH ONE SPECIES OF MYRMICINE ANTS.

Group 12. — *Camponotus pennsylvanicus*, *Formica sanguinea* and *Formica subsericea* with *Stenamma fulvum*; workers of each species.

ONE SPECIES OF PONERINE ANTS WITH ONE SPECIES OF MYRMICINE ANTS.

Group 13. — *Stigmatomma pallipes* with *Stenamma fulvum*; queens of the former with workers of the latter.

ONE SPECIES OF PONERINE ANTS WITH ONE SPECIES OF CAMPONOTINE ANTS.

Group 14. — *Stigmatomma pallipes* with *Formica subsericea*; workers of each.

ONE SPECIES OF PONERINE ANTS, ONE SPECIES OF CAMPONOTINE ANTS AND ONE SPECIES OF MYRMICINE ANTS.

Group 15. — *Stigmatomma pallipes*, queens and workers, with workers of *Formica subsericea* and of *Stenamma fulvum*.

In my artificial mixed nests, there is a close affiliation of ants of different species. Those of different subfamilies sometimes lick one another. Introduced young is carried about and taken care of without regard to its origin. Ants of one genus accept regurgitated food from those of another genus.

Ants appear to associate readily with all harmless familiars. In the wild nests of *Stenamma fulvum* I often see gray sowbugs roaming about, and they do not molest the ants, nor are they molested by the ants. On my putting a sowbug into an artificial nest of these ants, they seemed to treat it sportively, two or three young ants sometimes mounting upon its back and riding there, like children making excursions on an elephant. In my artificial mixed nests, small ants often ride on large ones, or stand on their backs and lick their heads.

Natural mixed nests probably originate among ants that seek in their abodes the same degree of moisture and of warmth. The habitat of each species being determined by the food-supply, the humidity and the temperature, any two species finding the same

habitat a congenial one, might form a mixed nest through an accidentally close association of their newly-hatched members.

Were the occupants of my artificial nests free to seek the habitation most agreeable to each species, they would doubtless soon separate. Perhaps they would never quarrel with each other on meeting; but they would certainly fight with all ants whose age and lineage were not the same as their own, or else the same as that of their quandam associates in the artificial mixed nest.

MARINE BIOLOGICAL LABORATORY,
WOODS HOLE, MASS., September, 1903.

A CAUSE OF FEUD BETWEEN ANTS OF THE SAME SPECIES LIVING IN DIFFERENT COMMUNITIES.

ADELE M. FIELDE.

If the blood of several ants of the same species be shed upon a morsel of sponge, the characteristic odor of the species is discernible upon the sponge, even by human nostrils. The odor may be pungent, acid, acrid, or musty, or may be like that of an animal or vegetable oil. Of the thirty-five hundred known species of ants, probably each has its distinctive odor.

Every ant recognizes its acquaintances through their odor and its own sense of smell. It is violently hostile to all ants bearing an unfamiliar scent, and is caressingly friendly with ants whose odor it has always known.

That ants of unlike species should be inimical one to another is less strange than the fact that those of the same species and variety, inhabiting the same localities, but living in different communities, should be as intensely antipathetic as are those of different species. With a view to ascertaining the cause of the animosity between such communities, I made in 1902, many experiments[1] with *Stenamma fulvum*, with results showing that the odor of the ants changes with their age, and that ants will not live amicably with those much older than any that inhabited the nest in which they were hatched.

If an ant be hatched in isolation, and the isolation be maintained until the ant has attained its adult strength and color, the odor of its own body is this ant's sole criterion of proper ant-odor, and it will affiliate with no ants other than those of the same lineage and of nearly the same age as itself. It will affiliate instantly with the queen-mother from whose egg it came and whose odor it inherits, and will identify and caress that mother though she be presented among five queens never before en-

[1] A. M. Fielde, "Notes on an Ant," *Proceedings of the Academy of Sciences of Philadelphia*, December, 1902.

countered. It will also affiliate with any of her progeny of the same age as itself, or with the progeny of her own sister of the same age.

A difference of forty days in the ages of two ants produces a difference of odor appreciable by the ants. If many pupæ be taken from one colony, and the workers hatched therefrom on the same day be segregated; and then, later on, more pupæ be taken from the same colony and the workers hatched therefrom on the same day be likewise segregated and established in a nest with inert young, the younger group of ants will not permit the members of the older group to approach the young in their nest, provided always that there be forty days or more of difference in the age of the two groups. The degree of animosity exhibited is in direct ratio to the difference in the age.

An ant hatched in the first brood of a solitary queen associates during its earliest days only with its queen and with its sister-ants, all hatched in one summer. These workers know only ants that are less than a year old, and will never become acquainted in a friendly converse with ants older than themselves. As seasons pass, and more ants are annually hatched from the eggs of this queen or the queens among her offspring, the latest comers know the odors of those of their own year, and of each year gone by, up to that of the oldest in the common nest. One might say that the sense of smell in the ant is more highly cultivated if she live in an old community.

I have been personally acquainted for four years with the ants in a community, the C colony, whose domain is a hundred yards in its diameter. On August 22, 1901, I took queens, males and workers from the wild nest of this colony, and segregated a similar group in each of two Fielde nests, where I kept them two years. The queens were winged when captured, and were doubtless less than a month old. The workers were fully colored, and may have been a year or more older than the queens. No young was permitted to hatch in either nest, and there was no communication between the two nests nor with outside ants. On August 25, 1903, I united the two groups, then numbering four queens and twenty-five workers in one nest, and two queens and nineteen workers in the other nest. They all affiliated in-

stantly with no sign of cognizance of their long separation. They had added years simultaneously and there was no difference of odor to occasion distrust among them.

I then introduced into the nest of the two united groups several very young ants taken that day from the wild nest. These callows were kindly received because the old ants all recognized an ant-odor with which they had formerly been acquainted, and this recognition was instant notwithstanding the fact that they had met no callows during two years. It is probable that an ant remembers during its lifetime any odor with which it has once been acquainted.

I then brought queens and workers from the same wild nest, housed them with their inert young in one of my artificial nests and left them to establish their nest-odor. A few days later I introduced into their nest marked queens and workers from the groups segregated two years previously. The marked queens were instantly accepted by the queens and workers in the latest nest. The marked workers were amicably received by all the queens, and by most of the workers in the latest nest, while a few nabbed them or dragged them away from the pupæ-pile. They were not killed but were denied by these few, the crowning mark of antesteem, permission to share in the care of the young. It thus appeared that ants as old as were these sequestered workers were not common in the summer of 1903 in the wild nest of the C colony, while queens two years old were known to all the ants taken from the wild nest.

Difference of food, drink and environment during two years had not caused a difference of ant-odor between the segregated ants and their ancient comrades.

The progeny of queens of unlike age but of the same community are unlike in odor.

Four queens of the C colony, captured by me before their swarming and while they were still winged, on August 22, 1901, were segregated with kings of their own colony in one of my nests which I here refer to as Section A. Two queens of the same colony hatched on August 5, 1902, from pupæ taken from the wild nest two days earlier. They mated with kings of their own colony on August 22, 1902, and were later on segregated

with workers hatched in my artificial nests between August 8 and 28, 1902, from C colony pupæ. This nest I here refer to as Section B.

The ants in the two sections were fed with the same kinds of food on the same days and had in all respects similar environment.

On July 12, 1903, an ant-worker hatched from a pupa that had been previously removed from Section B, and isolated in a Petri cell. This worker was kept in isolation until she was six days old. I then introduced into her cell a worker, the offspring of a queen in section A, and she attacked this worker with great violence, although the worker was of an age precisely her own and had likewise been isolated from the pupa-stage. The only difference between the two lay in the age of their respective mothers, one queen mother being two years old and the other one year old. Neither of these callows had, previous to their meeting, ever smelled any other ant, and had they had the same odor they would have affiliated, as do similarly reared ants that are the progeny of the same queen or of sister queens.

On August 24, 1903, when the ant from Section A, used in the foregoing experiment, was forty-three days old and was occupied in the care of introduced larvæ, I put into her Petri-cell, where she had always lived alone, a callow five days old, reared in isolation from a pupa taken from Section B. The resident ant at once attacked and dragged the callow. In this case the offspring of the older queen attacked the offspring of the younger queen, though that offspring was much younger than herself.

Other experiments coincided in their results with the two here recorded.

A cause of feud between ants of the same species living in different communities is a difference of odor arising out of difference of age in the queens whose progeny constitutes the communities, and difference of age in the ants composing the community.

MARINE BIOLOGICAL LABORATORY, WOODS HOLE, MASS.,
September, 1903.

DIMORPHISM IN BLISSUS LEUCOPTERUS.

J. F. GARBER.

Two forms of the chinch bug are recognized by entomologists — the one having wings fully developed, the other having wings more or less abortive. Between the two extremes of fully winged and almost wingless all gradations exist. Where the short-winged form occurs it is usually intermixed with long-winged individuals. Such a mixture appears at certain times in abundance in the timothy meadows of northeastern Ohio. It was from Trumbull, Portage, Mahoning and Stark counties of this state that Professor F. M. Webster furnished the principal portion of the material for the present study.

The study was undertaken with the direction of Professor C. B. Davenport to determine by quantitative methods the biological significance of the dimorphism.

Method.

The insects examined represented several random collections from different points. For study they were taken from the various bottles with no attempt at selection so those studied are presumed to present fairly the conditions in the whole group.

Where practicable, the wings were carefully removed from the body and mounted in a series on glass slides. By means of a dissecting microscope of low power and a camera lucida the image of the wing was projected upon a magnified scale and the length thus read to tenths of a millimeter. With museum material it was necessary to measure the wings in situ and this was accomplished by the use of a metal scale divided to fifths of a millimeter placed against the wing under a lens.

The Frequency Polygons.

The size of a class was fixed at one fifth of a millimeter and this gave a range of ten classes. The polygon is bimodal, one mode being at 1.5 mm. and the other at 2.7 mm. The extremes of the range include from 1 mm. to 2.99 mm.

For convenience in calculation the polygon was considered as two, the first having six and the other five classes, the small connecting class being divided between the two polygons. Both polygons are skew, running down very rapidly on their outer slopes and shading off gradually toward each other to be connected by a very small class. The skewness of the polygon with the mode at 1.5 mm. is + .0235 and that of the one with the mode at 2.7 mm. is — .018.

An examination of short-winged specimens from California and from Long Island kindly loaned from the National Museum by Dr. L. O. Howard and others from New York State loaned by Dr. C. E. Felt gave polygons with the same mode as that obtained from short-winged material from Ohio. Similar results were obtained by a comparative study of long-winged insects sent from Urbana, Ill., by Professor S. A. Forbes. This indicates that the tendency of a given form is toward the same mode from whatever region taken or whether the two forms are mixed or separate.

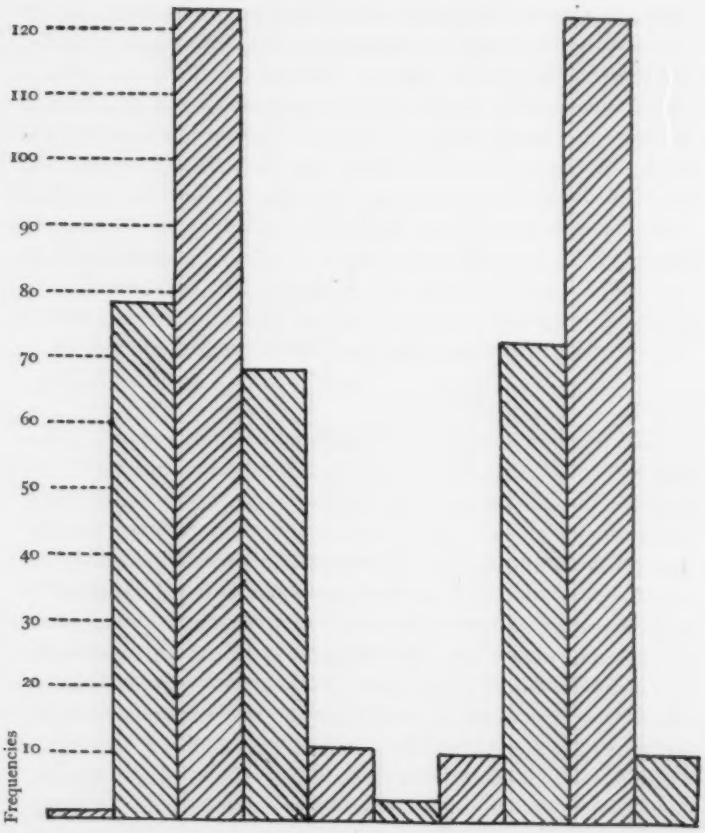
Discussion of Results.

The significance of these results is by no means easy to determine. Looking at the polygons only it seems reasonable to suppose that the present dimorphic species has been derived from a parent stock with a mode lying somewhere between the two present ones. In that case it may be assumed that differences of environment have permanently impressed themselves, dividing the parent stock into two evolutionary lines one of which at present has wings longer and the other wings shorter than the parent stock.

The evidences of geographic distribution appear to negative this view. The genus is almost cosmopolitan, having been reported from every continent save Asia and from many islands of the sea. So far as known, it is most abundant and certainly most destructive in the United States. Nevertheless there are good reasons for regarding the chinch bug not as a native but as an immigrant. In his very reasonable hypothesis about the origin and distribution of the chinch bug in North America, Professor Webster (1898)[1] assumes that our stock of chinch bugs has come

[1] Webster, F. M., "The Chinch Bug," U. S. Dept. of Agriculture, Bulletin No. 15, New Series.

from South America by way of the Isthmus of Panama, Central America and Mexico. The north-flowing stream was divided first by the Cordilleran system, one branch of the division following the Pacific Coast northward, the other, by far the more im-

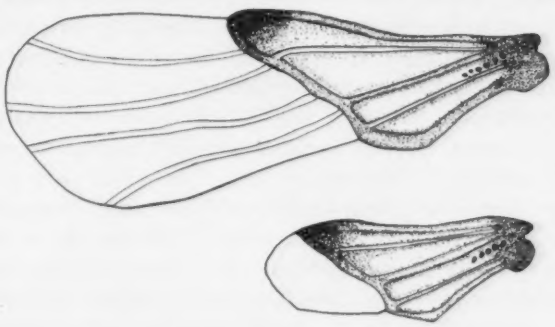


portant one, spreading over the Gulf States, was split again by the Appalachian Mountain System. One of these latter branches overflowed the Mississippi Valley; the other, following the coast of the Atlantic, finally rounded the north end of the mountain system and finding a congenial highway across New York State

joined the Mississippi Valley branch in northern Ohio and around the Great Lakes.

The short-winged form, so far as known in America, is confined to the ocean coasts and the immediate vicinity of the Great Lakes. The vast interior region from Central America to Manitoba abounds with only the long-winged form.

If Webster's theory is the correct one, we can scarcely escape the conclusion that the short-winged form originated in the regions where it is at present found. No short-winged specimens have ever been reported from the Gulf States outside of Florida, from Mexico or Central America, nor west of the Alleghanies,



notwithstanding, the insect is common in those regions and the short-winged form has been carefully looked for in some of them. The long-winged insects, then, appear to have been the ancestral form in America as far as history and hypothesis can give a clue. There seems to be an inherent tendency in the species to produce the short-winged form when the proper ecological conditions are provided. How the species acquired this tendency is a very difficult thing to understand and it is not the purpose of this paper to attempt an explanation of a phenomenon that appears to be older than the division of Heteroptera into the present recognized families.

According to Saunders[1] dimorphism is exceedingly common among British Heteroptera and this caused much confusion

[1] Saunders, Edward, F.L.S., "The Hemiptera — Heteroptera of the British Islands," 1892.

because long- and short-winged forms were placed in separate species, certain other correlated characters, *e. g.*, a weaker developed pronotum in the short-winged form being constant.

In the Family Lygeidae all grades of winged shortening occur and in some species a fully-winged individual is very rare. Indeed every important family shows wings shortening to some extent.

Though the short-winged form occurs in America almost exclusively near large bodies of water such proximity is not necessarily a factor in producing and preserving this peculiar character.

A closely related species, *B. doriæ*, is comparatively abundant in southern Europe and far northward into the interior of Hungary. A long-winged specimen of this species is a rarity and was not supposed to exist until 1880 when a very small colony was discovered by Professor Sajō. From his paper, presented in full in Professor Webster's bulletin previously cited, we get the facts concerning this species.

The colonies of *B. doriæ* live on the bases of bushy grass near or even under the surface of the ground, and here the stages of development are passed through. The species is very widely distributed on sand drifts and in hilly regions, but long-winged specimens were found in but a single tiny spot. The bunches of grass on which the insect lives are isolated in partially bare ground. During the period of development, *great drought prevails*. The long-winged specimens possess a stronger and broader thorax than the short-winged ones, and it never attacks cultivated crops.

According to numerous observers cited by Professor Webster, the habits of *B. leucopterus* along our coasts are almost identical with those described for *B. doriæ*. Professor C. W. Woodworth writes me that the chinch bug is found in California chiefly in the salt marshes.

Summary.

Where short-winged chinch bugs occur in Europe and America their habitat almost without exception compels them to live about the roots of tufts of grass on a soil otherwise almost bare. In California they are found in salt marshes. In Europe it may

be added that the developmental stages occur at a season of great drought. Taken all together we have a picture *par excellence* of a xerophilous insect which is only another way of designating a species capable of withstanding hard or unfavorable conditions of living. Among the hard conditions which are responsible for dwarfed wings as well as more or less dwarfed bodies of chinch bugs, I should place first drought and poor food supply. Latitude and climate do not influence them, but edaphic conditions that may extend over large areas are the potent factors.

The only recorded observation that seems to oppose this view is that of Mr. E. P. Van Duzee.[1] He states that in portions of Ontario and New York where the short-winged form usually predominates, in dry, hot summers they mostly acquire fully developed wings. It seems possible, however, that a dry hot summer added to an ordinarily unfavorable habitat may have destroyed the short-winged form to an extent, only those in the most favored places being allowed to develop.

That the short-winged form should extend at times beyond the borders of the particular habitat which served to develop the dimorphic tendency (as occurs for example in northern Ohio) may be regarded only as the persistence for a time of a character acquired by the race even when the insect is in different surroundings. The mixed forms, however, always cling to old food habits as far as possible, taking by preference to grass meadows instead of attacking grain fields as do the long-winged insects of the interior.

[1] Van Duzee, E. P., *Canadian Entomologist*, Vol. XVII., pp. 209–210, 1886.

UNIVERSITY OF CHICAGO,
June, 1903.

ON TWO CASES OF MUSCULAR ABNORMALITY IN THE CAT.[1]

RAYMOND PEARL.

The muscular anomalies here described were found by the writer in specimens of the domestic cat used for dissection in class work in the University of Michigan. As both of the cases presented certain interesting features it seemed advisable to publish an account of them at this time.

I. A Case of Abnormal Insertion of the M. Latissimus Dorsi.

In the cat the tendon of insertion of the M. latissimus dorsi normally is in two parts. One of these parts is joined by the muscle and tendon fibers of the M. teres major, and the conjoined tendon of these two muscles is inserted on the medial side of the shaft of the humerus. The other portion of the latissimus tendon, which may not be always present according to Reighard and Jennings,[2] joins with the pectoralis minor, reaching the bone along the line of insertion of the pectoralis minor. This line is along almost exactly the middle of the ventral face of the humerus. As a consequence of the existence of their different lines of insertion the two portions of the latissimus tendon form an arch, which makes up a part of the bicipital arch.

In a well-formed, adult male cat dissected by the writer the very peculiar arrangement at the insertion end of the M. latissimus dorsi shown in Fig. 1 was found on both sides of the body. From the cranial border of the latissimus a slip (Fig. 1, *x*), about 4 cms. long and 6 mm. wide passed craniad above that portion of the latissimus which joins the pectoralis minor (Fig. 1, *y*). This slip was inserted by fleshy fibers on the surface of the M. pectoantibrachialis on the medial surface of the leg, just beneath

[1] Contributions from the Zoölogical Laboratory of the University of Michigan, No. 65.

[2] Reighard, J., and H. S. Jennings, "Anatomy of the Cat." New York, 1901 p. 121.

the skin. This band of muscle formed a very distinct, rather thick slip.[1] The relations of all the other muscles of the leg were normal. The two tendons of insertion normal to the latissimus dorsi were present and in their usual relations. The abnormal slip was simply added on, as it were, to the muscles normally present.

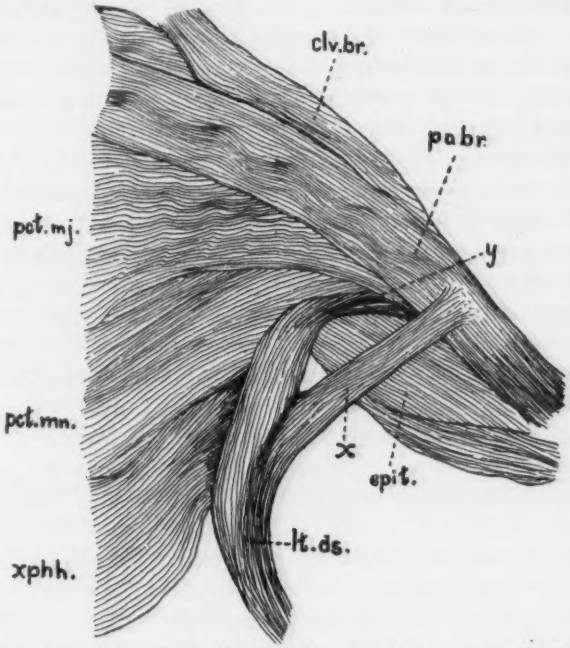


FIG. 1. Ventral view of left side of the thoracic region in cat, showing abnormal insertion of the M. latissimus dorsi. *clv. br.*, M. clavobrachialis; *pabr.*, M. pectoantibrachialis; *epit.*, M. epitrochlearis; *lt. ds.*, M. latissimus dorsi; *xphh.*, M. xiphihumeralis; *pct. mj.*, M. pectoralis major; *pct. mn.*, M. pectoralis minor; *x*, abnormal slip of M. latissimus dorsi; *y*, portion of the latissimus dorsi which joins the pectoralis minor.

The conditions found in this case of the latissimus dorsi inserting in three portions, one of which does not reach the humerus at all, is apparently unique. So far as I have been able to dis-

[1] In another cat dissected by a student in the laboratory precisely the same arrangement was found, except that the mucle slip was much thinner than in the case here described. Only a few fibers reached the pectoantibrachialis.

cover no record of such a condition has been made in teratological literature, nor is such a condition found normally in any form. In most mammals[1] the latissimus inserts by one tendon; in some forms (*e. g.*, the cat) usually by two; and finally as a variation, which apparently occurs with some frequency, it inserts by two tendons in forms where it normally has only one. This last is the condition in man.[2]

The condition found in this abnormality to a certain degree resembles morphologically what is normally found in many mammals in the M. epitrochlearis. This muscle, in the majority of cases, takes origin from the surface of the latissimus dorsi near its insertion, and is inserted into the superficial fascia of the forearm and the olecranon. This muscle is usually regarded as a differentiation product of the latissimus dorsi. It is possible that the present abnormality may indicate that originally the M. epitrochlearis had in the carnivora a greater extent at its insertion, extending on to the superficial fascia of the upper as well as the forearm. Further than this I am not able to make any suggestion regarding the significance of this abnormality. On account of the fact that apparently such a case had not been described, it seemed desirable to make a record of it.

II. A Case of Connection between the M. Cleidomastoideus and the M. Levator Scapulæ Ventralis.

The M. cleidomastoideus normally forms a distinct muscle in the cat, taking its origin from the apex and caudal margin of the mastoid process of the temporal bone. It passes caudad, flattening during its course, and is inserted on the lateral four fifths of the clavicle and laterad of the clavicle on the clavicular raphe. This clavicular raphe is formed between the Mm. cleidomastoideus and clavotrapezius (= M. cleido-occipitalis + cleido-cervicalis Streissler)[3] craniad, and the M. clavobrachialis (= Pars claviculi

[1] Cf. Leche, W., Mammalia, in Bronn's "Klassen u. Ordnungen des Thier-Reichs," Bd. 6, V. Abth., 1874–1900, pp. 722–725.

[2] Cf. Le Double, A. F., "Traitè des Variations du Système Musculaire de l'Homme," Paris, 1897, T. I., pp. 194–202.

Testut, L., "Les Anomalies Musculaires chez l'Homme," Paris, 1884, pp. 106–118.

[3] Streissler, E., "Zur vergleichenden Anatomie des M. cucullaris und M. sterno-cleidomastoideus," *Arch. f. Anat. (u. Physiol.) Jahrg.*, 1900, pp. 335–365, Taf. XXI. u. XXII.

of M. deltoideus of earlier writers) caudoventrad. At its insertion the cleidomastoid lies entirely beneath the clavotrapezius. Lying close besides the cleidomastoid (dorsad and in part mediad) is the M. levator scapulæ ventralis (= M. omo-transversarius Streissler, *loc. cit.*, = Pars ventralis of the M. omo-cleidotransversarius Leche, *loc. cit.*, = "omo-trachélien" Le Double, *loc. cit.*). This muscle in the cat takes origin by two heads, one coming from the basis cranii opposite the middle of the bulla tympani, and the other from the ventral surface of the transverse process of the atlas.

In a well-developed adult female cat dissected by the writer, the following abnormal relation of the cleidomastoid and the levator scapulæ ventralis was found on the left side of the body. At almost precisely the middle point of the levator scapulæ ventralis a thick muscle band, approximately 4 mm. wide, passed from the ventral border of this muscle cranioventrad to the dorsal border of the M. cleidomastoideus, with which muscle it joined. The connecting band was throughout its length of approximately the same thickness as the Mm. cleidomastoideus and levator scapulæ ventralis at the places where it joined them.

In considering the significance of this abnormality the possibility of its representing a case of reversion may be dismissed at once, because in their comparative anatomy the cleidomastoid and levator scapulæ ventralis are known to be quite distinct muscles. The M. cleidomastoideus is a differentiation from the general sternocleidomastoid group of muscles, which in turn is to be considered as having separated from the trapezius group.[1] It belongs to the rather thin, superficial sheet of muscle which covers the dorsal, lateral and part of the ventral surface of the neck, and the dorsal surface of the cranial thoracic region in all the Mammalia. This sheet of muscle breaks up into varying numbers of separate muscles in different groups. All of these muscles, however, as has been very clearly brought out by Streissler (*loc. cit.*), fall into either a dorsal or a ventral group. The dorsal group may be characterized as the dorso-scapularis-trapezius group, and the ventral as the sternocleidomastoid group. All the muscles of this superficial layer are innervated primarily

[1] Cf. Leche, *loc. cit.*, pp. 701–706.

by the N. accessorius, with, in some cases, fibers from the cervical plexus going to the muscles of the ventral group. The levator scapulæ ventralis or omo-cleido-transversarius, pars ventralis (Leche) belongs to an entirely different set of muscles than those just considered. According to Leche[1] it is highly probable that this muscle is a differentiation product of the muscle group from which the M. levator scapulæ comes. It is innervated by fibers from the ventral branches of the spinal nerves.

Evidently then, since the cleidomastoid and the levator scapulæ ventralis have such different sources the abnormality under discussion cannot be considered as a reversion.

The abnormality does, however, seem to be suggestive as possibly giving us light on the meaning of the conditions found in man with reference to the muscles of the ventral neck region. In what manner will be apparent if the relations in man are considered briefly. The M. omotransversarius (*i. e.*, levator scapulæ ventralis) is normally found in some form or other in practically all mammals up to man. In man it is only occasionally present as a separate muscle in abnormal cases. It has been a problem how to account for the absence of this muscle under normal conditions in man, and no satisfactory explanation for it has ever appeared so far as is known to the writer. On the other hand the human sternocleidomastoid is, of course, a complex muscle, made up by the fusion of elements normally forming distinct and separate muscles in the lower forms. Streissler[2] has shown that this muscle contains at least the following elements: In the superficial portion a sternomastoideus superficialis, a sterno-occipitalis and a cleido-occipitalis element; and in the deep layer a sternomastoideus profundus and a cleidomastoideus element.

The fact that occasionally the omotransversarius appears in man as a distinct muscle may be taken as strong presumptive evidence that in all cases the muscle is present in man as an element in the ventral neck musculature. Why it is not found under normal circumstances is because it is indistinguishably fused with some other muscle. In the abnormal cases where it does appear as a separate muscle we most probably have simply

[1] *Loc. cit.*, pp. 731–735.
[2] *Loc. cit.*

a failure to fuse or only partial fusion, where normally complete fusion occurs.

The abnormality here under consideration has suggested to me the view that *normally in man the omotransversarius element is fused completely with the cleidomastoid portion of the M. sternocleidomastoideus.* This view would make the sternocleidomastoid a complex of six elements, as shown in the following scheme:

M. sternocleidomastoideus (Man) {
- Sternomastoideus superficialis
- Sterno-occipitalis
- Cleido-occipitalis

} Superficial.

{
- Sternomastoideus profundus
- Cleidomastoideus
- *Omotransversarius*

} Deep.

The evidence for this view comes from two sources. In the first place, the occurrence in anomalous cases in man of a separate M. omotransversarius makes it extremely probable that this element is generally present in man, but in normal cadavers is completely fused with some other muscle. In the second place, the anomalous case in the cat just described shows that in a form lower than man it is possible for a partial fusion of the cleidomastoid and omotransversarius muscles to occur as a variation. This makes it seem probable that the muscle complex with which this omotransversarius element in man normally fuses is the sternocleidomastoid.

Summary.

1. A case of insertion of a portion of the M. latissimus dorsi on the M. pectoantibrachialis is described.

2. A case of partial union of the Mm. cleidomastoideus and levator scapulæ ventralis (or omotransversarius) is described.

3. The view is advanced that the human sternocleidomastoid muscle contains an omotransversarius element. This element is normally completely fused with the deep portion of the sternocleidomastoid, but, in abnormal cases, it may fail to fuse completely and consequently then appears as a separate muscle.

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BIOLOGICAL BULLETIN

OF THE

Marine Biological Laboratory

WOODS HOLL, MASS.

VOL. VI NOVEMBER, 1903 No. 6

CONTENTS

		PAGE
H. F. THACHER.	*Absorption of the Hydranth in Hydroid Polyps.*	297
C. M. CHILD.	*Form Regulation in Cerianthus...*	304
ADELE M. FIELDE.	*Artificial Mixed Nests of Ants..*	320
ADELE M. FIELDE.	*A Cause of Feud between Ants of the Same Species Living in Different Communities...*	326
J. F. GARBER.	*Dimorphism in Blissus leucopterus.....*	330
RAYMOND PEARL.	*On two Cases of Muscular Abnormality in the Cat.....*	336

PUBLISHED MONTHLY BY THE

MARINE BIOLOGICAL LABORATORY

PRINTED AND ISSUED BY
THE NEW ERA PRINTING COMPANY
LANCASTER, PA.

AGENT FOR GREAT BRITAIN	AGENT FOR GERMANY	AGENT FOR FRANCE
WILLIAM WESLEY & SON	R. FRIEDLÄNDER & SOHN	LIBRAIRIE ALBERT SCHULZ
28 Essex Street, Strand London, W. C.	*Berlin, N. W. Carlstrasse, 11*	*2, Rue Le Goff, 2 Paris, France*

Single Numbers, 75 Cents. Per Volume (6 numbers), $3.00

Entered October 10, 1902, at Lancaster, Pa., as second-class matter, under Act of Congress of July 16, 1894.

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